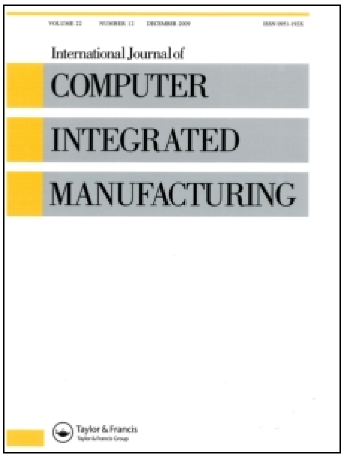

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Interface tool for human communication to integrate psychophysical inputs with rapid manufacturing technologies

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People with Special Needs (PSN) are people conscious or unconscious with limited motor skills (possibly owing to a post-surgical situation). A large number of these persons have problems in body areas in contact with support surfaces. They do not have the capacity for autonomous movement, which results in excessive skin pressure and restricted blood circulation. This can lead to the development of pressure ulcers (PU). These people do not have the opportunity to communicate their needs to qualified care givers/helpers in the area to obtain appropriate products based on recent technologies. It is important to have integrated tools which allow PSN to interact with the technologies that surround them. This system permits strategies that allow personal psychophysical data to be analysed by a specialised technician (highlighting the user's verbal and nonverbal signs), originating data that can be of assistance in the process of conversion into 3D computer aided design (CAD) models. From these models is expected a shape/base with better pressure distribution and able to be manufactured using technologies such as rapid manufacturing. This analysis considers user communication with a specialised technique based on pressure measurements, dynamic body posture and comfort/discomfort as verbal or nonverbal signs. The aim is to create an integration system that induces human communication, as a bridge between psychophysical data and a technique to use rapid manufacturing technologies for highly personalised product development.

Keywords: rapid manufacturing; psychophysical inputs; semiotic; product design

1. Introduction

People with special needs (PSN) are people conscious or unconscious with limited motor skills or owing to a post-surgical situation. A large number of these persons have problems in body areas in contact with support surfaces (Aksnes 2004). They do not have the capacity for autonomous movement, which results in excessive skin pressure and restricted blood circulation. The result is the development of pressure ulcers (PU).

According to Blanes *et al.* (2004), PU are cutaneous wounds of the soft part, superficial or deep, of ischemic origin, caused by an increase in external pressure, and usually located on a bony prominence. A visual diagnosis can classify the ulcers in stages that are important for the elaboration of therapeutic strategies (Aksnes and Whittet 2006).

The PU are caused by extrinsic and intrinsic factors. The four extrinsic factors are pressure, humidity, friction and shearing. The main factor contributing to PU is pressure and the pathological effect on the skin can be attributed to its intensity and duration and to the skin tolerance.

On the other hand, Shen and Parsons (1997), Kyung and Nussbaum (2008) and Vink and de Looze (2008) have studied the comfort/discomfort feature connected with the product and its interaction.

Comfort is more closely related to emotional experiences and expectations, where the interaction with the product depends on environmental and psychological factors. For example, a red room may seem warmer than a black room, a glass chair may be perceived as less solid or safe than an iron chair. Discomfort is more closely related with physical aspects, such as pressure and physical features (temperature and humidity).

The literature shows that discomfort, the most considered aspect, is easier to measure because it is more objective and is perceived in regard to the context, the product and user-related physical aspects. Comfort is a subjective and more complex aspect that depends on a psychological context. According to Vink and de Looze (2008), 'everyone has his or her opinion on the comfort of product' and the variability of emotions is always present, the probability of changing one's opinion owing to a product is real. That means that because everyone has a different relationship to the comfort of a product, it is not easy to validate a standard to determine what the best product or

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comfort feature is. This allows us to determine discomfort problems in an objective and measured way and makes it possible to connect the interaction of users to reduce product discomfort.

The act of sitting is a good way to understand user-centred design needs in connection with the final product and has been the objective of a large number of research studies. Short- and long-term studies have explored the relationship between pressure level and the perceived comfort or discomfort of a person with regard to the seat (Schifferstein and Hekkert 2008).

People with PU problems do not have the opportunity to communicate with technicians to obtain appropriate products based on recent technologies to improve the quality of their lives. It is important to have integrated communication tools that allow communication between disabled people and technologies.

This work aims to contribute to an improvement in the well-being of users with special needs, by preventing pressure ulcers. This contribution is based on the extraction and communication of information from PSN in an integration that uses communication between the user and specialised technicians to develop personalised products by means of rapid manufacturing.

Based on user-centred design methods, the developed system is built up between the user's psychophysical data and the communication with the specialised technicians, allowing the assemblage of a set of information that can be used to develop personalised products.

The data extracted from the user are subjected to analysis and evaluation by a specialised technician with the ability to interpret human signs, whether that information results from a transaction-based process (such as the case of the pressure maps), or from a communication-based process where a set of pragmatic information (for instance humour or other factors external to the evaluation process) needs specialised interpretation and communication.

To carry out the work, the 'core system' is programmed using the LabView application. The open integration system has been designed to integrate different contributions from a large amount tool work of communication such as users, suppliers and manufacturers. The quick evolution of technologies develops strategies to manage resources and information. This situation leads to an integration system where all parts of the process work in a dynamic system with the same block of information. New global economies cause the relocation of industries. On the other hand, the cost of resources, and especially stock, changes the manufacturing philosophy into a low or personalised production, where more parts contribute to a network. An example of this new reality is the information system that changed the relationship between software and client. Now the systems try to manage all the information by network in only one data base.

In some cases this core system can reduce business costs, avoiding the duplication of information, and be managed just in time. The system process covers all processes steps from the idea concept to the final product, based on a network, that quickly changes the processes used with manufacturers, suppliers and buyers. On the other hand, the strategy for a market based on user-need satisfaction leads to personalised product design. For this reason, the 'core system' is a module-based integration system that can add new modules in response to user needs and satisfaction.

2. System description

2.1. Pressure system

The Body Pressure Measurement System™ (BPMS) is based on a flexible matrix of piezoresistive sensors (Wilson and Bush 2007). The system creates a pressure map and expects a synchronised connection with other systems to monitor and register the best pressure map or study other questions such as pressure exposition time, movement and posture. Pressure systems usually collect qualitative information based on the interaction of the user with the surface and permit a quick reading of the pressure region. The pressure region is shown as numerical mmHg values or graphics in two or three dimensions.

The sensor matrix is composed of n rows and m columns on flexible material which helps to adapt to each type of surface.

From the pressure acquisition technologies it is possible to acquire numerical values, but there is other communication information to study. In order to understand the development of pressure in real time, communication between the user and the technician is required. Semiotic information such as skin colour and muscular strength interact with different technologies, like the discomfort questionnaire (the BorgCR10) and motion capture (MOCAP), and can interfere with the interpretation of results.

2.2. MOCAP/motion capture

Motion capture (MOCAP) is a motion measurement system constituted by a set of cameras arranged around a patient to collect data movement. This system tracks retro-reflective markers distributed on several strategic points on the patient's body (Wilson and Bush 2007). The measured motions collected permit the seating posture to be studied using a flexible pressure sensor matrix (Andreoni *et al*. 2002).

MOCAP can be used to acquire anthropometric information and also as a complementary tool for the assessment of a patient's emotional state. Emotional states may be directly communicated and interpreted, as in the case of a questionnaire, but they may also be communicated unconsciously, as for example when patients change their facial expressions, in which case a qualified technician needs to analyse them.

2.3. *Discomfort range*

Various PU studies connect pressure scales and comfort/discomfort features. One of the six most important scales is the Borg CR10. This scale, based on the physiopathology of PU, works with two determinants considered critical; the intensity and duration of the pressure and the skin tolerance (Shen and Parsons 1997).

A primary tool for seating comfort evaluation is based on the pressure distribution measurement at the seat occupant interface, and excessive prolonged sitting in any region of the interface will induce compression discomfort (Shen and Parsons 1997). The main specifications in seat design are pressure magnitude reduction and uniform distribution of pressure, but establishing the relationship between surface pressure and seating comfort is difficult.

The measurement of discomfort itself is problematic. The sensation of discomfort is generic and subjective, negatively affected by human psychological homeostasis, psychological well-being, or both, when they occur together. Measuring pressure discomfort is a psychophysical problem. A convenient and widely used approach is a rating-scale technique to measure intensity and assess comfort. Studies that apply these methods show that subjects are able to make a direct judgement of sensations without the need for a standard contrast stimulus.

The literature on the scaling properties of rating scales for postural and seating discomfort does not give any experimental results, but some studies have been carried out with localised postural discomfort (LPD) questionnaires such as the CR10 scale developed by Borg (Shen and Parsons 1997), numerical ratings of perceived exertion (RPE) and other physical features (Schifferstein and Hekkert 2008).

Although some scales are more complex, the CR10 scale is one of the most efficient because it is based on only 10 points and provides a clearer result.

2.4. *Core system*

The core system is an open design system based on modules and developed in 'LabView' to collect and analyse a large amount of information. The core system helps computer aided design (CAD) and computer aided manufacturing (CAM) systems to make a better designed product personalised to user needs.

The interface module interacts first in an acquisition system with human communication. Psychophysics experts can work with signs and make information judgments to validate what type of information it is and when in time it can be analysed. In fact, the two most important types of information are pressure based on technologies with the possible direct transaction of information (objective information), and questionnaires, facial expressions, movements, humour and the environment, based on human communication (subjective information).

According to Putnik *et al*. (2005), it is possible see from de Moor and Weigand's Table 1 that in virtual enterprise integration (VEI) system semiotics, information is connected at different semiotic levels.

After the interface module and validation of the psychophysics expert's analysis, the information can be used to generate a virtual three-dimensional (3D) pressure map. In the 'seat design module', a subsystem in the core system, 3D pressure maps can be converted into 3D XYZ coordinates to obtain point clouds with seat shape possibilities. The dynamic relation can be considered with a material feature and a

Table 1. Virtual enterprise integration semiotics (Putnik 2005).

Virtual Enterprise Integration processes		
Semiotic Levels	Aspect	Characterization
Social		social requirements, culture
Pragmatic	*Focus*	communication,
	Support	communication process,
	Design objects	"fuzzy" process-definitions
	Devt. Process	continuous,
	Developers	many stakeholders
	Change	dynamic
	Responsibility	individual
	Design process	interpretation
	Objective	perceive, understand, value, act
	Control logic	norms
Semantic	*Focus*	information,
	Support	transaction process,
	Design objects	clear specifications
	Devt. Process	single project,
	Developers	elite development team
	Change	static
Syntantic	*Responsibility*	anonymous
	Design process	representation
	Objective	control
	Control logic	rules
Empirical		component architecture,
Physical		technical infrastructure

manufacturing process. In the end the design module generates an ASCII file to help CAD do 3D drawing and some outputs to consider manufacturing choices and CAM.

3. Methodology

The aim of this project is to create an integrated system by which personal psychophysical data can be analysed, converted into a 3D CAD system and used with rapid manufacturing technologies. A cluster of different technologies, all integrated toward a common goal, leads to a final solution, as shown in the flow chart of Figure 1. The integrated system explores the interaction between patient and seat. These factors demonstrate that it is a system which uses communication to aid communication between patients and technicians.

According to de Moor and Weigand (in Putnik *et al*. 2005), 'The information systems built on the information field paradigm do not produce sterile data, but aim to generate and communicate information that can lead to true knowledge that helps people to perceive, understand, value and act in the world.'

The method is based on information transaction and information communication systems. First, the process is based on information transaction where a pressure map can be obtained based on pressure acquisition system. The map data can be processed in the 'core system', an application developed to perform information integration.

The information is captured using the sensor map and then, after validation by the specialised technician, it is transferred to the 'core system'. It is important to emphasise that this kind of information, like in information technologies, is of a semantic nature, which means that it is treated as impersonal, objective and susceptible to software and statistical manipulation, allowing standardisation.

Second, part of the information systems results from the communication between the user and the specialised technician. Through the questionnaire (the Borg CR10) or the video capture (MOCAP), this communication provides a qualitative interpretation of the information. In this case technicians give shape to the information through by their judgement, perception and evaluation of the acquired data. It is important to mention that this process, unlike acquisition by pressure, is subjected to inputs of an individual nature, such as emotions or individual responses to the surrounding environment (sound, temperature, room colour, etc.).

In the case of the 'Interface to integrate psychophysical inputs in the design process' the method presented combines the various semiotic levels, whether semantic, pragmatic or others. This is expected to provide essential help to the design process.

3.1. *Pressure acquisition*

The pressure system, based on a flexible material embedded with a sensor matrix, is connected to hardware to permit data registration (Figure 2). Sensors in flexible material are calibrated with software that extracts pressure map measurements in mmHg.

After calibration, the system creates a pressure map, based on frames as long as required. The supplied software extracts pressure data and displays it on a numerical map or a 2D and 3D visual graphic pressure level (Figure 3).

On the other hand, the system works with either one frame or a set of frames and exports a report with outputs such as features, distribution sensors, total pressure, point pressure and patient feature in an ASCII document. The connection with the core system permits a total synchronisation with a MOCAP registration that integrates both inputs, which leads to the analyses done by the technician of the critical point related to the patient and the base of the seat.

The method identifies the personal pressure feature and explores the relationship in relation to the Borg CR10 PU comfort/discomfort scale.

The Borg Scale is used to extract information from the user. The system developed is asked to rate the pressure stimuli by choosing a number on the scales shown in Table 2. It is permitted to use decimals and also to go above or below 10 or 0.5, if necessary.

The rating scale method was used. The items for paired rating included the sensations of:

(a) pressure intensity;
(b) discomfort level due to the stimulus;
(c) overall discomfort on the whole seat surface.

Other systems such as MOCAP also complement the Borg scale. MOCAP uses video recordings. Video permits an attentive study of movement, and of the transfer of mood connected with the pressure map, and gives some anthropometric data. Based on the pressure map report and the dynamic information from MOCAP, the system has information to rewrite a final report in an xyz document.

3.2. *Converting to geometric information*

The CAD software imports an xyz document that shows point clouds due to pressure and usage. This document is later transformed into a geometric mesh, or based on the points made into a set of spline to develop a loop. Anthropometric data from MOCAP

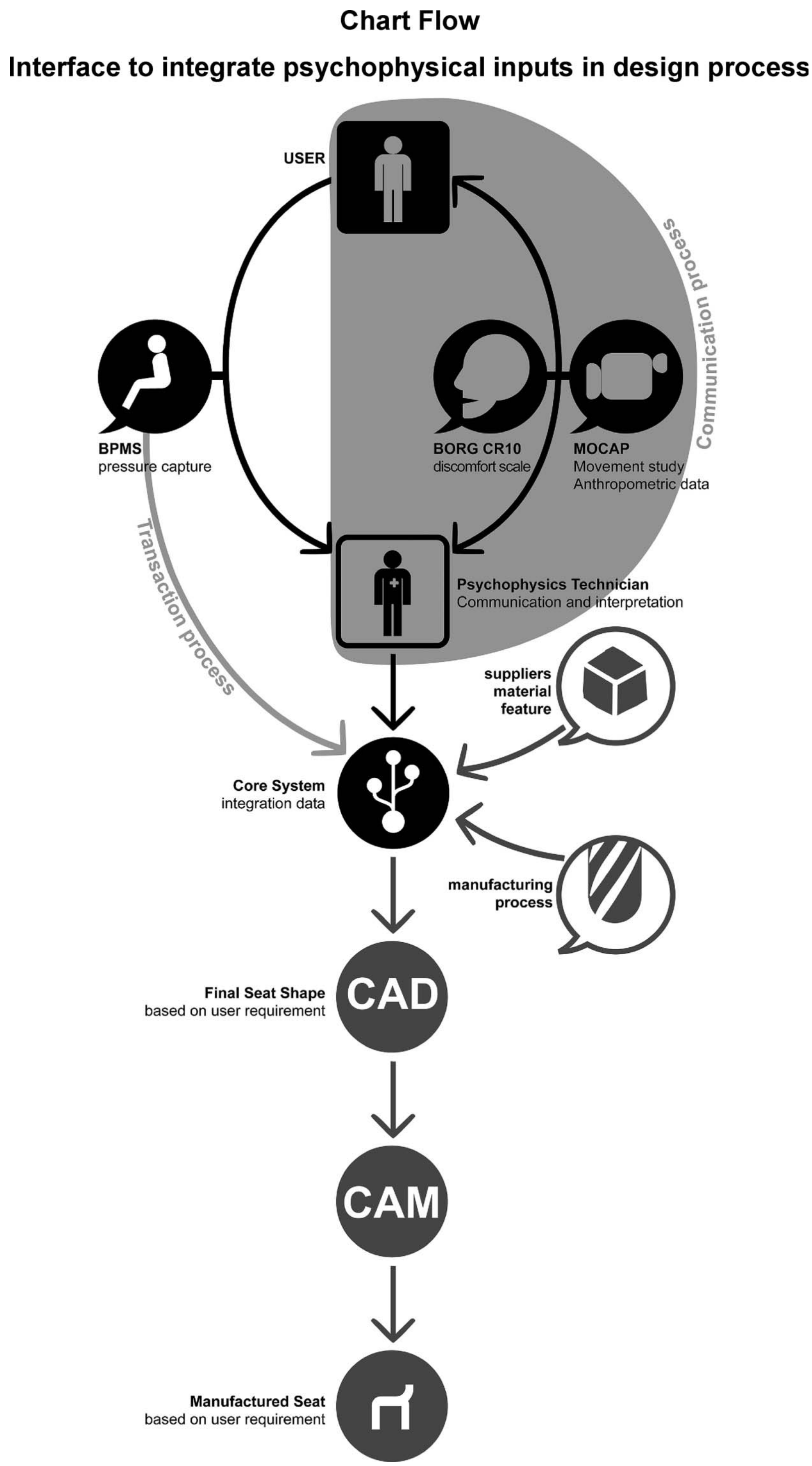

Figure 1. Methodology developed for the communication between patients and technicians.

personalises the 3D shape according to the pressure map and geometric information. The CAD system permits open data while simultaneously the system is preparing the mesh.

At this stage it is possible to eliminate noise in order to interpret a cloud point and to transform it into a mesh. It is important to study the technologies that improve the data management because sometimes different paths create the same results.

The first part of the test gives two different results. One is based on creating a spline and a loft, where the result created a bad rate shape. The other is directly

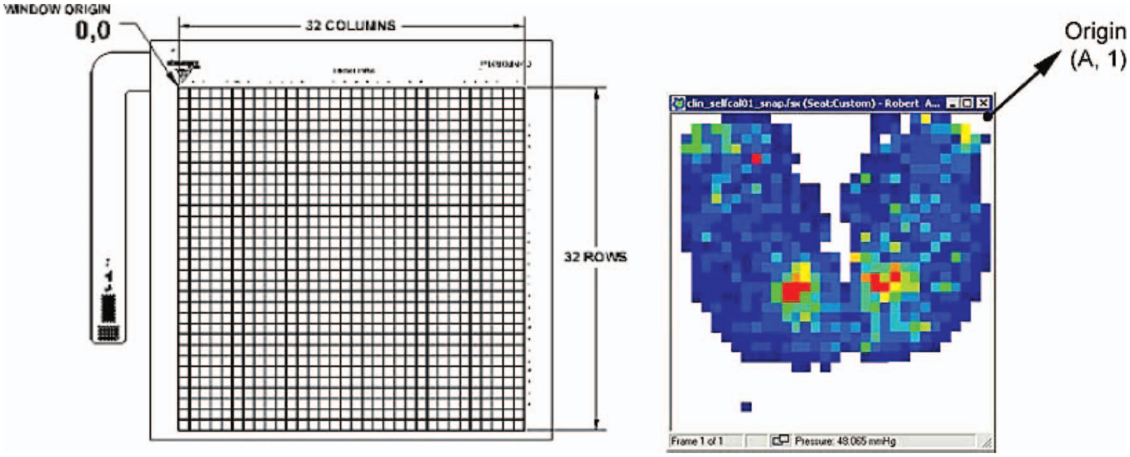

Figure 2. (a) Flexible material pressure sensors and (b) 2D pressure map (Courtesy: Tekscan).

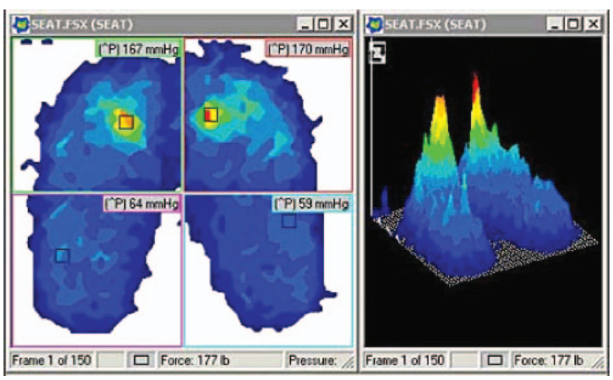

Figure 3. 2D and 3D map obtained from pressure acquisition system (Courtesy: Tekscan).

Table 2. Relation between rates and stimuli.

Rate	Description
0	None at all
0.5	Very, very low pressure/slight discomfort
1	Very low pressure/slight discomfort
2	Low pressure/slight discomfort
3	Moderate pressure/s discomfort
4	Somewhat high pressure/severe discomfort
5	High pressure/severe discomfort
6	
7	Very high pressure/severe discomfort
8	
9	
10	Very, very high pressure/severe discomfort

related with individual point clouds to create the mesh. The second stage is to understand how to approve this shape, and how to control it to have a better distribution of comfort.

According to the PU literature, one of the most important problems in the field is the bad distribution of pressure, especially in the ischial area, where the bone is more predominant. In the first part the system creates a physical geometric relationship, based only on pressure. In the second part the core system is connected with psychophysical data to determine the personal relationship with the seat.

Psychophysics (Aaen-Stockdale 2008) uses a set of tools related with the variables of stimulus and perception to make quantitative/qualitative judgements. The literature reveals that a lot of technologies have been used in work on the relationship between PU and psychophysics. Shen and Parsons (1997) describe six rating scales based on the validity and reliability for seat interface pressure discomfort.

The tools used to develop this system are a mixed set of technologies that help communication between users with special needs and technicians. After the pressure is acquired by the method explained in section 3.1, it is necessary to understand the different frames with pressure points and give a .txt report with all the information such as position sensors, user weight and pressure points.

MOCAP helps systems designed to acquire position and movement. Since the markers were attached during the scanning process, the system could obtain the relative position between markers and body position and pressure data. However, an interpretation of system communication made by the technician is important to check all data, to see if any is misleading and to validate the information collected.

The system then superimposes the body model onto video footage that is captured by a digital video camera in sync with the motion capture data to easily recognise the communication correlation between body movement and the patient's behaviour. It was necessary to display and fit the video footage and the body model on the same coordinates. The system accomplishes this by estimating the camera's parameters, including the following: position and orientation of the camera (extrinsic parameters) and focal length and principal point of the camera coordinates (intrinsic parameters). This information is obtained by using a camera calibration technique (Tsai 1987). The technique corresponds to the position of skin markers on the 3D space coordinate with the two dimensional (2D) video image coordinates. As a result of this superimposing technique, the system is able to observe and register body movements (Figure 4).

By combining the 3D model and the motion capture data, the system computes the transition of the body-embedded reference frame. The dynamic movement of the PSN patients was visually represented during several activities like the transition from the comfort/discomfort seat or the change of pressure areas. Using only MOCAP with dynamic information, the designed system does not have enough information because pressure information is misunderstood. A better interface measurement platform is necessary to help prevent pressure ulcers. The design system complements MOCAP data with dynamic pressure acquisition data. All this information will be used in processes to develop an adapted product. New rapid manufacturing technologies seem to be the appropriate processes to customise products resulting from the design system.

MOCAP and pressure acquisition as caption systems require further research into accuracy validation. Published works report that there are not any standards to compare real body position with measurements because caption markers are not invasively measuring internal body information (Otake *et al.* 2005; Wilson and Bush 2007). In these situations, it is considered that MOCAP and the combined pressure acquisition tool may become one of the tools used to non-invasively measure the bone position.

The designed system uses Excel to convert pressure information acquired to weight in a CAD system. By using these weights in CAD like a new map, the system generates the shape according to the patient. The CAD system is converting information from a .txt document into a 2D spline with a macro designed and developed for this purpose. With all this information in spline format, the designed system could produce a surface to meet patient feature requirements. Conversion from splines to surface is not done directly because the system design uses loft information to generate the final appropriate result.

This information is still not suitable to manufacture the shape because some mm values were too large. In the second step, the CAD system will be used to rescale and convert the shape to an acceptable weight. To do this the process uses information from anthropometric data correlated with coccyx weight and MOCAP information to reduce the Y scale to a maximum of 2.5 cm. Although the new surface was generated directly from user data, it was not a better surface because the control of the loft from splines is too complex, and the shape generated has accentuated line breaks. In order to solve this problem, another tool was studied and added to create a smoother shape.

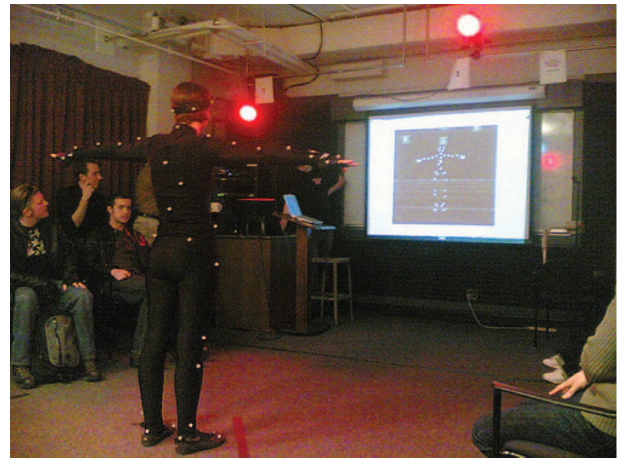

Figure 4. Marks to help with movement (Courtesy: Joshua Dickens).

Based on some connection with the results from the new steps, the system we designed is proposed to study how to work directly from a point cloud graph to a CAD system without splines.

One function was designed and developed to import the information from the map of matrix pressure and based on transforming X, Y and Z coordinates into importable data directly to a CAD system. All these data generate a point cloud and this function correlated the data imported and the weight of cushion. In these steps the CAD system allowed the point cloud to be opened directly and converted it into a mesh because it imports an XYZ document.

After all these steps, the designed system is too hard to use. For this reason, an interface was designed and developed in LabView. Now, the entire system is integrated into one tool which is more user friendly, and thus easier to use for the technicians (Figure 5).

This new interface tool has some new functions to enable better control of shape. As an example, since the curve of the surface was generated with pressure level values, and based on the Borg CR10, it is possible to understand the different levels of discomfort. The tool has a function to accent the variation values in a non-linear progress.

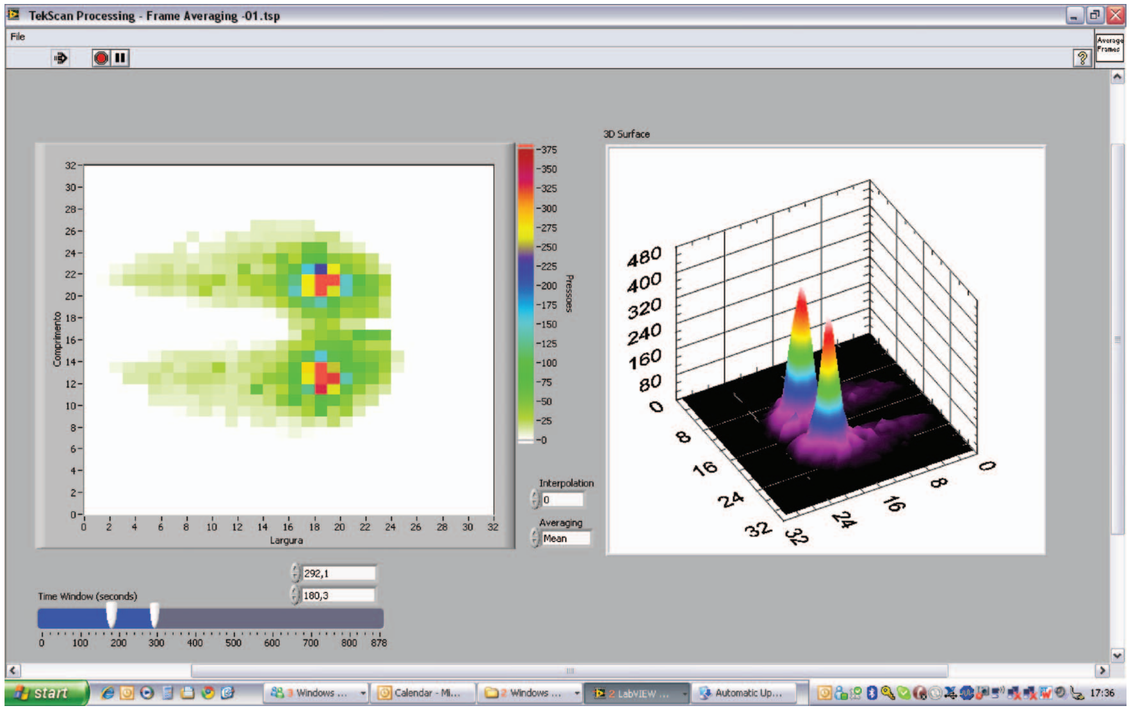

Figure 5. Interface tool screen from Core system.

3.3. *Manufacturing data preparation*

The end of the system chain is product manufacturing. The expected final result is the product that responds to user needs with a commitment to materials and a manufacturing process.

Because there is an integration system and an interconnection between the core system, and the CAD and CAM systems, it is possible to change the final manufacturing process based on CAD system information. The CAM system makes it possible to manage manufacturing process according to markets/suppliers.

After the manufacturing processes is decided upon, the information is converted to computer numerical control and sent to the machine which in turn finally machines the parts to makes the products.

4. Integrated system

The evolution of the integrated system has become increasingly complex. Technologies allow information to be acquired by using different software tools. Furthermore, systems could also do integration work with an integrated database but actual communication with an integrated system could only be done focusing on the interaction between elements involved in the process.

According to Putnik *et al.* (2005), 'Integration means putting together heterogeneous components to form a synergistic whole.' This is the same idea as computer integrated manufacturing (CIM), which tends to focus on centralised information in a single block and the sharing of the data base by all participants in the process business, which means reducing the costs of information duplication, access and interaction. These modules from different sources allow a dynamic/immediate relationship with the other parts of the process because the system is structured to integrate communication.

According to Cecelja (2002), 'A further use of IT/IS is the ability to collect and analyse a large amount of information relating to buyers, and establish which buyers are most attractive and which cost the business money.' This premise may also be applied to suppliers, manufacturers and manufacturing processes.

On the other hand, the business concept has shifted towards open models, which can share information with suppliers/sellers, or low production models such as personalised products in a total integration of the information and communication system as an answer to market strategies/needs.

This work focuses on user needs without only attending to technical data to develop a product to satisfy their needs but attending to personalised communication to obtain a well customised and unique product to satisfies those needs. For this reason this work integrates information and communication covering all development areas.

The system is divided by modules that are managed by a central module called the 'core system', programmed in an open system with the possibility to add new modules, or use data bases from networks in collaborative work (Figure 6).

First of all, the system is used to integrate user information with technologies to build a personalised product. Second, as an open system it could interact and be integrated with other stages of the product life cycle such as materials, suppliers or manufacturing technologies, even if they are located inside or outside the business chain and independently of their geographic location.

In the '*seat design module*' characteristics such as strength or height are considered to formulate the characteristics of the product when CAD and CAM are used. The chance to change or interact at any moment allowing adaptation of the market just in time is possible. This framework represents the activities in an integration-based module system.

The different activities are represented by a set of modules with filled-square broken lines. The filled-square continuous lines represent tools, while the broken arrow lines represent communication information and the continuous arrow lines represent transfer information. The circle represents dynamic actors of information. A special square with a broken bold line represents the 'core system module', the integration module of the whole system.

The first module is an acquisition module that represents the interaction with psychophysical tools and users that generate two types of semiotic information with different characteristics. The semantic information is clear, objective and quantitative (like the pressure map) and it is possible to measure and transfer it to the next module, while the more pragmatic information is confusing, subjective and qualitative, and needs a correct interpretation by the technician. This subjective information is dynamic, and some factors like humour and the environment can influence the result, or the relationship with psychophysical tools. Using this module, an expert can validate or make judgements. Both information types need validation after acquisition.

The 'core system module' makes the integration synthesis. It is based on information from the whole process, but especially from the acquisition and seat design module. The 'seat design module' works based on the core system and transforms the data pressure information into x,y,z geometric coordinates. This module draws in CAD a 3D seat shape, and is prepared to consider dynamic information from suppliers and manufacturers to redraw the shape, based on the manufacturing process.

The last module, the 'manufacture module', receives STL data from the seat design module in order to process the information in machine code.

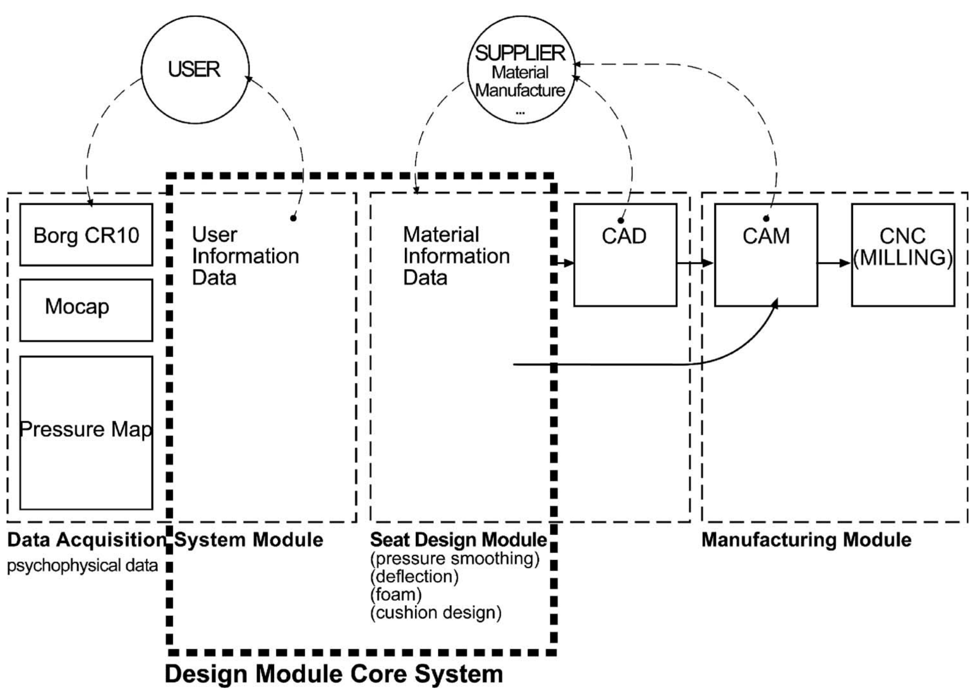

Figure 6. Integration system framework.

Table 3. Caption data from (a) experimental set-up; (b) optimised shape.

	1ª acquisition																															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	10	6	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	5	13	10	0	0	0	0	0	0	0	15	10	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	15	13	0	0	0	0	0	0	11	21	11	8	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	6	13	15	11	8	0	0	0	0	0	11	18	13	10	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	10	13	13	16	10	0	0	0	0	0	13	21	16	11	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	6	8	13	16	11	13	0	0	0	0	0	11	16	11	11	8	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	6	6	15	21	15	13	0	0	0	0	6	15	23	15	10	0	8	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	8	11	13	19	13	13	0	0	0	0	8	26	24	10	11	8	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	8	13	13	19	29	11	0	0	0	0	11	13	29	15	15	8	6	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	8	10	10	10	13	11	10	6	0	0	0	13	15	16	15	15	13	10	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	8	15	16	13	18	13	0	0	0	0	11	21	28	42	18	13	8	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	8	11	10	52	23	19	18	6	0	0	0	13	29	29	13	15	16	8	10	0	0	0	0	0
14	0	0	0	0	0	0	0	0	10	10	19	19	31	21	18	6	0	0	0	19	29	36	21	32	13	10	10	0	0	0	0	0
15	0	0	0	0	0	0	0	8	6	15	44	26	45	37	18	15	0	0	11	28	49	52	41	49	21	11	8	0	0	0	0	0
16	0	0	0	0	0	0	0	8	10	23	68	57	83	94	45	23	8	16	24	62	151	130	68	26	24	11	8	0	0	0	0	0
17	0	0	0	0	0	0	0	10	13	32	39	133	254	258	105	31	34	24	53	117	272	280	172	71	57	13	10	0	0	0	0	0
18	0	0	0	0	0	0	0	6	13	71	86	241	413	413	139	58	45	42	47	143	413	413	230	71	57	16	6	0	0	0	0	0
19	0	0	0	0	0	0	0	0	23	29	73	292	413	264	109	62	45	34	58	76	264	413	269	42	16	18	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	10	42	52	87	175	123	75	62	42	24	31	53	157	175	55	36	10	10	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	11	19	52	63	75	50	41	81	19	36	44	66	87	34	29	10	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	19	26	49	60	55	28	66	5	37	41	58	52	28	19	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	16	24	44	42	24	62	0	26	18	29	36	15	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	11	16	19	0	8	0	0	0	8	5	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(*continued*)

Table 3. (*Continued*).

	2ª acquisition																															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	0	0	0	0	0	0	0	0	0	0	15	16	7	8	31	8	0	0	0	13	5	0	15	10	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	13	15	8	13	23	13	12	0	0	0	13	12	10	16	18	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	16	10	7	28	15	16	12	0	0	7	15	12	13	12	28	25	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	10	16	20	20	12	15	28	20	0	0	7	13	13	13	13	15	13	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	16	16	20	18	26	16	25	26	0	0	10	20	23	12	12	23	13	7	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	16	15	30	21	18	18	21	21	0	0	7	21	20	15	13	15	13	15	0	0	0	0	0
6	0	0	0	0	0	0	0	0	8	13	16	21	16	13	25	23	33	0	0	13	15	30	15	16	28	18	20	0	0	0	0	0
7	0	0	0	0	0	0	0	0	10	13	13	21	21	12	20	10	10	0	0	16	21	30	20	21	33	15	12	12	0	0	0	0
8	0	0	0	0	0	0	0	0	10	18	20	25	16	20	23	16	30	0	0	20	26	23	18	31	15	26	16	20	0	0	0	0
9	0	0	0	0	0	0	0	0	13	18	25	30	25	23	13	25	26	0	0	31	20	31	25	46	26	20	28	18	0	0	0	0
10	0	0	0	0	0	0	0	0	15	33	23	40	20	25	38	35	43	0	0	40	31	31	33	36	28	20	20	15	0	0	0	0
11	0	0	0	0	0	0	0	0	21	23	36	31	15	33	30	30	31	0	0	40	33	49	40	40	46	46	25	16	0	0	0	0
12	0	0	0	0	0	0	0	5	16	28	40	36	43	20	25	44	44	0	8	49	35	59	44	41	31	20	44	15	0	0	0	0
13	0	0	0	0	0	0	0	0	16	25	40	53	26	38	59	48	41	36	40	51	53	26	31	36	25	35	31	18	0	0	0	0
14	0	0	0	0	0	0	0	0	30	30	46	35	58	30	81	63	48	43	64	43	59	74	64	59	46	31	26	23	0	0	0	0
15	0	0	0	0	0	0	0	0	15	31	36	74	99	115	91	64	61	49	33	51	102	130	234	125	48	54	31	16	0	0	0	0
16	0	0	0	0	0	0	0	0	25	30	69	69	191	196	135	69	20	35	59	59	135	351	280	219	84	40	25	18	0	0	0	0
17	0	0	0	0	0	0	0	0	20	30	69	125	237	237	176	66	63	49	43	66	64	224	235	202	110	46	21	10	0	0	0	0
18	0	0	0	0	0	0	0	0	0	23	46	109	142	184	97	76	63	64	63	54	79	107	102	100	86	56	21	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	15	31	48	53	72	71	77	56	56	66	58	58	46	66	49	33	25	5	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	20	30	43	18	48	61	49	64	51	56	82	66	46	41	35	5	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	15	28	28	36	33	43	33	20	43	46	40	21	33	8	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	23	26	20	23	0	13	20	38	23	12	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The present system represents a set of subsystems that integrates all parts of the process precisely because the approach used for its development was based on the communication process method. This means that although we have an integrated system, it is possible to change inputs in each semi module, and those modifications are reflected in the final result.

5. Results analysis

The experiment consisted in applying the designed system which converts psychophysical data into a customised shape in a CAD platform. In order to carry out the first step, the psychophysics laboratory collected information using a flexible matrix of pressure sensors, MOCAP system and the Borg CR10 questionnaire. Because the designed system works with psychophysical data, the contribution from the Borg CR10 is required to permit analysis of the level of discomfort based on the interpretation of the frame pressure map supplied by matrix sensor software in a text report. The patient is 26-year-old woman with 52 kg of body weight.

First, a pressure map at 50 Hz was collected where maximum pressure is at 413 mmHg and has been associated with the most intense moment of discomfort – 7 out of 10 based on the technical questionnaire filled in by the PSN patient during the experiment. The pressure map obtained according to data in Table 3 is shown in Figure 7. It permits an understanding of the pressure distribution of different seat regions related to patient features. By studying pressure ulcer profiles, the generated system could evaluate the pressure area and, combined with the Borg CR10 (Table 2) system, could be combined with psychophysical data. Figure 7(a) shows a 3D graph of the pressure map presented in Table 3(a). This map is the result of the acquired pressure on a plane seat. Figure 7(b) shows the 3D graph of the pressure map presented in Table 3(b). This map is obtained through an optimisation of the pressure distribution that results from a new seat shape generated from the map in Table 3(a), making it possible to understand the difference made by maximum pressure and better distribution. A prototype is generated to check how suitable it is to design and develop an interface which helps to generate a customised shape in order to improve the quality of life. The results based on a new seat shape and collected in a calibrated way show the reduction from a pressure of 450 mmHg (Table 3(a)) to 351 mmHg (Table 3(b)) in the most problematic region and the better pressure distribution to be used in the designed system.

Figure 8 shows the conversion from an Excel spreadsheet to surface on a CAD system by following the steps of splines, lofts and surfaces.

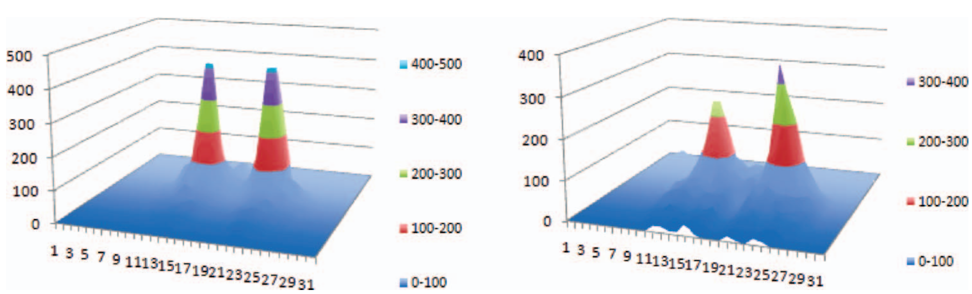

Figure 7. 3D representation of pressure map of (a) experimental set-up; (b) adapted tools for prototype system.

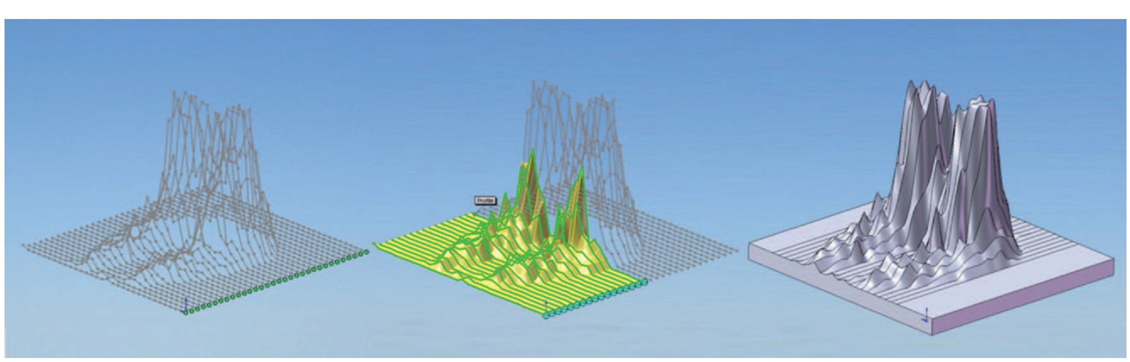

Figure 8. Several views on CAD (splines, loft and surface) for experimental set-up.

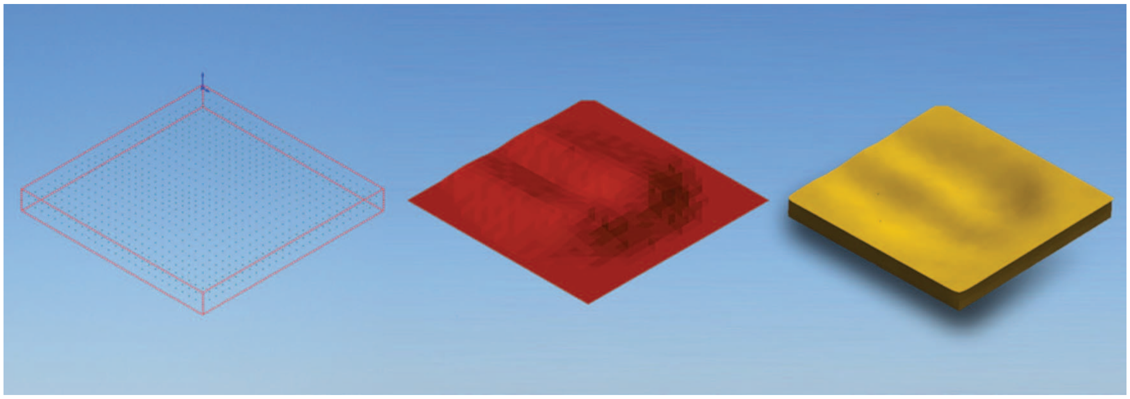

Figure 9. Shape created by system designed to satisfy patient needs.

Once the system has converted the acquisition data to surface shape, the interface tool designed with LabView is used. As explained in this work, the interface tool converts directly from acquisition data to clouds of points introduced in CAD systems. CAD systems import point clouds as x, y and z coordinates through xyz documents to a shape to be manufactured following patient requirements (Figure 9).

In the case study it was only applied to the direct relation from the data pressure gathered from the user and the generation of seat shape, to correct the bad pressure distribution and correct, if possible, certain discomfort problems.

6. Conclusion

This study is focused on PSN, especially persons that need to stay seated for long periods, which frequently causes pressure ulcers. This paper studies a case study related to one of the most important problems of pressure ulcers and sitting. Although it is a complex situation involving many inputs like humidity, surfaces and temperature, it could be said from other studies that the pressure problem is the most important to solve. This case study shows how the system information is based not only on information transaction but also on information communication. The semiotic levels are integrated and used through the integration system in the case study.

The present system suggests creating tools which will interact and connect user signals to the technical apparatus while making this reliable. This opens a new field in product design, especially in the health area, to solve special needs. This work demonstrates the importance of working with communication processes to connect users and technicians and develop appropriate and adjusted products. The core system, by integrating information of different natures, supports technological work using communication between people with special needs and technicians. This core system improves the technological aspect of product realisation work and facilitates the communication process.

The designed integration system combines several tools that can convert pressure acquisition data to shapes on a CAD system. The shape information obtained contributes to reducing pressure and a better distribution, improving the quality of life of people with special needs.

This integration system is prepared to solve other situations because the interface tool used acquires and converts psychophysical data to technical requirements.

This project presents a new way to think about product design and manufacturing processes by extracting information from PSN who have difficulty communicating. This system will help technicians to manufacture customised product solutions. Future works will introduce technologies such as rapid manufacturing, which seem to be the best solution for customised products.

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